Particle Dynamics in the Bottom Boundary Layer at the Coastal Mixing and Optics Experiment Site

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LONG-TERM GOAL

My long-term goal is to generate measurements of particle concentration and settling velocities as function of particle sizes; these data are central to modeling sediment transport in the BBL.

OBJECTIVES

My objectives were to *(a)* measure the size-dependent particle concentration and settling velocities with the use of newly developed instruments funded through this program. These instruments, LISST-100 and LISST-ST employ the principles of multi-angle light scattering and a mathematical inversion of these measurements for estimating the particle concentration in 32 log-spaced (equi-phi) intervals. The measurements were to be made from a tripod placed on the bottom; *(b)* the second objective was to examine the measurements in conjunction with bottom stress measurements made by the BASS velocimeter array placed nearby.

APPROACH

I developed a tripod, with releases and a float-based recovery system for use in the course of the experiment. Two LISST-100 and one LISST-ST instrument were built and placed on the tripod. The LISST-100 instruments (measuring size distribution from multi-angle measurements of laser light scattering) were vertically separated to observe gradients in concentration and size distribution. The LISST-ST was placed a 1-m above bottom. The tripod also served as a platform for other instruments, notably the marine aggregates camera of Dr. Paul Hill (Dalhousie Univ.) and the BIOPS package of Tommy Dickey (U of Southern California). The tripod is displayed in the photograph below.

WORK COMPLETED

In all, 4 tripod deployments were made at the Coastal Mixing and Optics site. The instruments delivered data through the entire period, including through several hurricanes that passed in the vicinity of the site.

Data analysis has been carried out and a paper detailing particle dynamics at the CM&O site has been submitted to the special issue of the Journal of Geophysical Research [*Agrawal et al.*, 1999]. A paper

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describing the instrumentation has also been submitted after revision [*Agrawal and Pottsmith*, 1999]. A third paper on settling velocities is currently under prepration.

RESULTS

The first result of the program is the successful development of a new generation of instruments that provide size-specific concentration of suspended sediments in the water column. As all prior theoretical and empirical work recognizes the importance of particle size in establishing the vertical concentration distribution, this marks a significant development.

A second unfunded and unexpected development is that of the discovery of a new optics principle for the measurement of true suspended sediment concentration. Unlike all prior measurements of suspended sediments where the calibration of the sensors was known to depend on the (unknown) particle size distribution in water, this measurement maintains its calibration over a 200:1 range of variation in particle sizes. The principle is embodied into an instrument, the LISST-25. In addition to the total suspended sediment concentration, this 2-parameter measurement also delivers a mean size.

The scientific results are presented in a paper by Agrawal and Traykovski (1999). These results show (a) that a simple relationship exists between mean particle size and mean current stress and height above bed; (b) that vertical gradients in the size distribution do indeed exist in nature as has been predicted for several decades; (c) that the concentration of sediments through a storm showed an initial decrease before increasing – explained by the small current stress and disaggregation of particles in the wave boundary layer; and (d) that the aggregation and disaggregation of particles plays a first order role in the overall dynamics of particles in the bottom boundary layer.

IMPACT/APPLICATION

The implication of the size distribution measurements are clear and significant: that particle size changes vertically, (*a*) that a simple empirical relationship between current stress, height-above-bed and mean size exists, and (*b*) that settling velocity data are available for particles typical of the BBL. Furthermore, (*c*) the most dramatic result is shown in figure 1, where the size distribution measurements reveal that even though transmissometry suggests an increasing sediment concentration in the early stages of hurricane Edouard, the reality was that particle break-up caused increased beam attenuation, despite a reduced suspended mass concentration. This obseration underscores the importance of size distribution. The data are expected to be the basis for improved models of sediment transport in the BBL .

An impact of this work is on the availability of these instrument systems through commercialization at this company. In particular, the simpler LISST-25 which delivers the size-independent constant calibration measurement of sediment concentration and mean size, is likely to alter the way sediments are measured in the future. The switch from old sensors to this new one is already under consideration by a major European government.

TRANSITIONS

All instruments developed in the course of this work have been transitioned to the commercial world with investment of internal R&D funds from the company. A large number of scientists all over the world are using these instruments for studies of sediment transport.

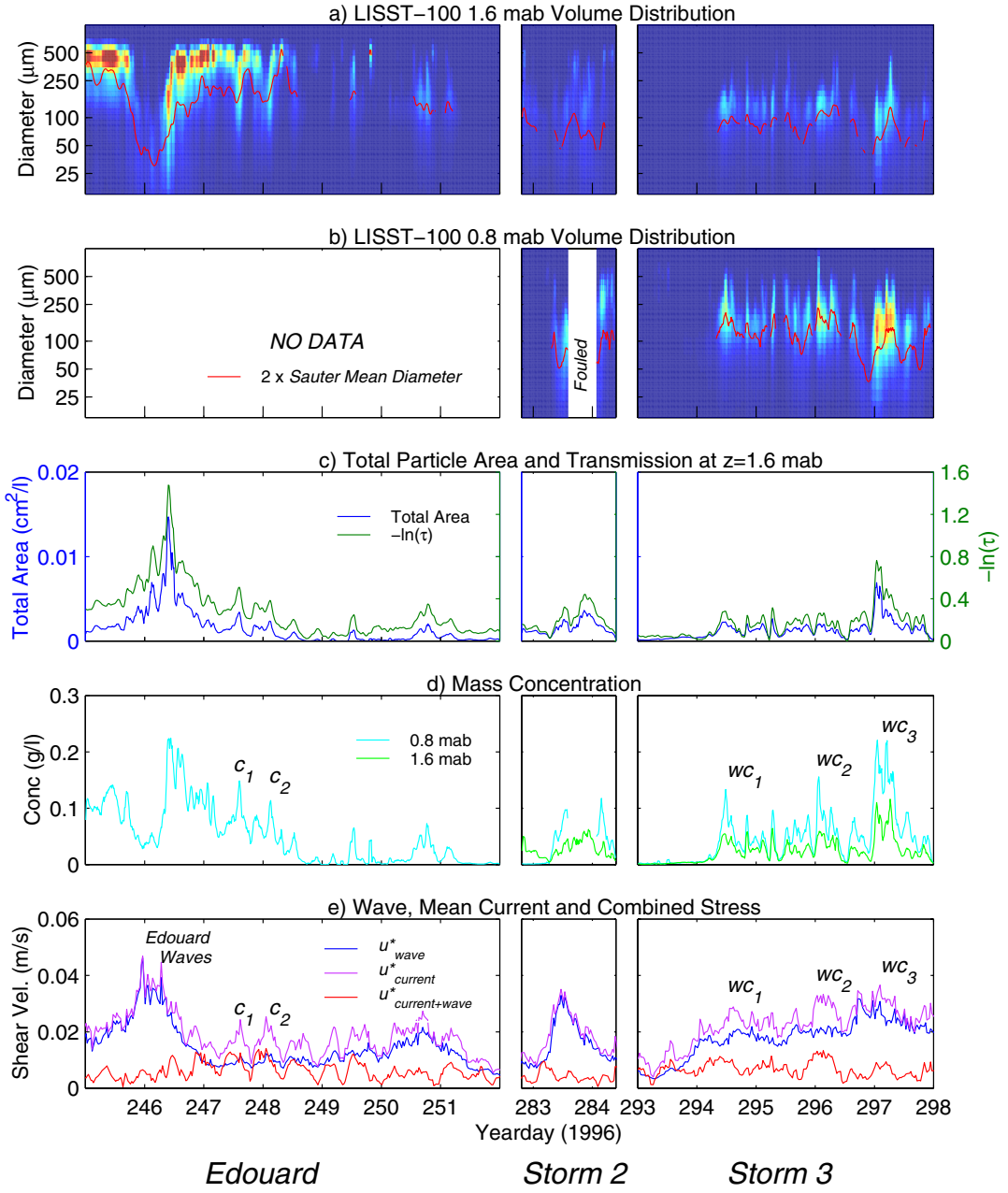

Figure 1: This figure shows particle size distributions at two elevations above the seafloor in a 1996 bottom boundary layer experiment south of Cape Cod, Massachusetts. Two LISST-100 instruments were placed on a tripod, respectively, at 1.6 and 0.8 m above the seafloor. The top two panels show the size distribution; the red line running through them shows the Sauter Mean Diameter. In panel c, the 'particle concentration' estimated from optical transmission is displayed [since transmissometers measure total particle area, the 'concentration' and total particle area estimated from LISST are shown for comparison, with excellent agreement]. In panel d, the total suspended mass concentration is shown, while the bottom panel shows the stresses due to currents and waves. In the initial part of hurricane Edouard, the total sediment concentration (panel d) shows a slight decrease, and at the same time, the SMD also decreases (panel a) although the reducing SMD causes an increased attenuation (panel c). This is interpreted as large particles breaking down to smaller ones due to turbulent tearing, creating a situation where transmissometer estimates of concentration are erroneous. Note that the true total concentration from LISST agrees only qualitatively with transmissometer measurements in the rest of the record due to changes in particle size distribution.

[from Agrawal and Traykovski, 1999, Jour. Geophys. Res. (submitted).]

RELATED PROJECTS

1 – In the ONR sponsored HYCODE project, the same suite of instruments is now being used for the characterization of mixing of bottom sediments througout the water-column.

2 – In an NSF sponsored project, along with measurements of dissipation rate in the wave boundary layer, data on suspended sediments will be acquired south of Martha's Vineyard, Massachusetts. This is part of my continuing research in bottom boundary layer dynamics and sediment transport.

PUBLICATIONS

Agrawal, Y.C., and H.C. Pottsmith, Instruments for Particle Size and Settling Velocity Observations in Sediment Transport, *Marine Geology*, *(submitted)*, 1999.

Agrawal, Y.C., P. Traykovski, and A.J. Williams, Particles in the Bottom Boundary Layer: Concentration and Size Dynamics through Events, *Jour. Geophys. Res.*, *(submitted)*, 1999.